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Portraits in Science

Mr. Edward H. Heinemann is Vice President Engineering and Program Development of General Dynamics Corporation in New York. He has been identified with airplane design and development for most of his career, which started with the Douglas Aircraft Company in 1926. Heinemann's more famous designs include some naval aircraft: SBD Dauntless Dive Bomber, AD Skyraider Attack Bomber, F3D Skyknight Jet Night Fighter, A3D Skywarrior Jet Heavy Attack Bomber, F4D-1 Skyray Jet Interceptor, F5D-1 Skylancer, and A4D Skyhawk Jet Light Attack Bomber. Heinemann also designed the first research aircraft directed toward supersonic flight, the D-558 Skystreak Jet and the D-558-2 Skyrocket, the first aircraft to reach twice the speed of sound. Heinemann is a fellow of the Royal Aeronautical Society and the American Institute of Aeronautics and Astronautics. Among his honors Heinemann has received the Sylvanus Albert Reed Award and the Collier Trophy. At the present he is affiliated with ONR as Chairman of the Naval Research Advisory Committee.

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Superconducting Devices: A Cool Solution to Navy Problems?

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INTRODUCTION

The coldest temperatures of the North Pole are scorching heat by comparison with those that physicists and engineers routinely create in their laboratories today for the purpose of studying physical phenomena. At extremely low temperatures near absolute zero (−275° Centigrade or 0° Kelvin), many strange phenomena occur in nature which at higher temperatures are masked by the random heat motion of atoms and electrons. One of these is the flow of electric current in wires with zero resistance, for indefinite periods of time. This phenomenon has fascinated scientists for over half a century, but it is only within the last decade that the properties of superconducting materials have found practical utility, both civilian and military. A whole host of technological applications has resulted, ranging from powerful magnets to infrared detectors and ultrasensitive sensors of minute magnetic fields. What is perhaps most intriguing is the potential of exploiting superconductivity during the next decade in ways which will literally revolutionize our present defense technology while at the same time providing significant spin-offs to medicine, controlled thermonuclear power, electric power transmission and many other sectors of our society. The story of the development of this field of superconductivity is an interesting and illuminating example of how the support of basic research by ONR and other DOD agencies, from the mid 1940's to the present, is now resulting in the transformation of intriguing laboratory techniques into the realm of military and industrial practicality. This transformation will have profound implications in a number of areas, ranging from anti-submarine warfare, to communication, to navigation, to propulsion and to the entire field of electronic systems. No single development, with the possible exception of controlled thermonuclear fusion, holds the promise of realizing such vast technological applications. Even controlled thermonuclear fusion is dependent on superconducting magnets, if it is to be economically feasible. Instruments, devices and measuring techniques of an accuracy,

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sensitivity, reliability and efficiency heretofore undreamed of are being developed under DOD support. The transistor, the laser and now superconducting devices are all prime examples of where basic research, with appropriate husbandry, yields developments of great import.

HISTORY OF SUPERCONDUCTIVITY

The story of superconductivity had its genesis just a little over a hundred years ago when in 1868 a British astronomer observed unusual spectral lines from the hot incandescent gases of the chromosphere of the sun, using a newly invented instrument called a solar spectroscope. These spectral lines could not be accounted for as being produced by any known substance on earth at that time. Thus the gas was given the name "helium" deriving from the word "helios," the Greek word for sun. Twenty-seven years later (1895), Sir William Ramsay, a British chemist, discovered helium on the earth and, in 1908, Kammerling Onnes in the Netherlands succeeded in liquifying helium gas at a temperature of −269°C, or −452°F (some four degrees above absolute zero).

Three years later, in 1911, Onnes noted that as he gradually cooled a specimen of mercury to the temperature of liquid helium, the electrical resistance of the mercury dropped suddenly from a finite value to zero (Figure 1). Try as he did, he was unable to measure any detectable electrical resistance. Thus he concluded that mercury had passed into a new state, which because of its extraordinary electrical property he called the superconducting state. It was soon discovered that this low temperature zero resistance state was widespread among many elements,

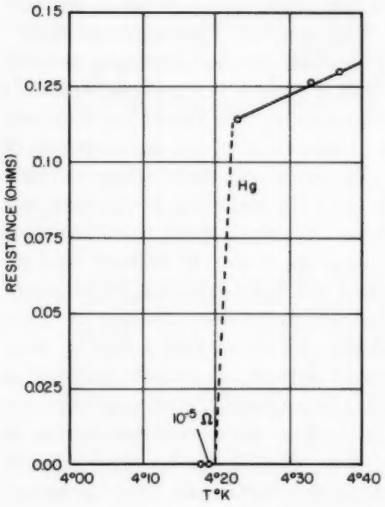

Figure 1 — Resistance in ohms of a specimen of mercury versus *absolute temperature. This plot by Kamerlingh Onnes marked the discovery of superconductivity in 1911.*

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alloys and compounds including such common metals as lead and tin. The temperature at which a material transforms from its normal resistive state to a state of perfect electrical conductivity is called its transition temperature, T_c. For tin, this transition temperature is 3.7°K (−269.4°C) and for lead its T_c is 7.2°K (−266°C). (Transition temperatures have been measured from 0.015°K to slightly above 20°K.) The total disappearance of electrical resistance has been carefully measured and shown to be at least a factor of 10^{17} smaller than the dc resistance of copper at room temperature. For example, superconducting rings of tin have been made to carry circulating dc currents of more than an ampere for periods of up to a year, disconnected from any battery, without any measureable decrease in current. Thus the electrical resistance of superconductors may for all practical purposes be assumed to be zero.

It was first thought by Onnes and others that the zero resistance property could be exploited to build magnets with very high magnetic fields simply by winding a coil of appropriate material made into wire and passing a large electrical current through the coil when cooled below its transition temperature. This electrical current would persist without any decay or heating and one would have very powerful electromagnets with zero power loss. Unfortunately it was soon discovered that the presence of a magnetic field of modest value (less than 1000 gauss) would destroy the superconductivity in the materials known to Onnes. Since one could build iron core electromagnets with magnetic fields of above 20,000 gauss, superconducting magnets appeared to have little value at that time.

In 1930 hopes were raised when alloys were discovered which were able to retain superconductivity in fields of 20,000 gauss or more but they proved a failure as far as practical applications were concerned. Although they were able to withstand high magnetic fields, they were incapable of being formed into wires that could carry high electric currents.

In 1933 two German physicists, Meissner and Ochsenfeld discovered another unique property of superconductors. They showed that a superconducting body completely expels an externally applied magnetic field as it passes from the normal to superconducting state (Figure 2). This property of magnetic impermeability, or perfect diamagnetism,

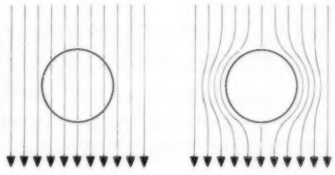

Figure 2 — Meissner effect in a superconducting sphere cooled in a constant applied magnetic field; on passing below the transition temperature the lines of magnetic induction are ejected from the sphere

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came as a surprise, because it cannot be inferred directly from the property of perfect electrical conductivity. A superconducting body below T_c exhibits perfect diamagnetism and excludes magnetic fields up to some maximum value whereupon it reverts to the normal state. The highest magnetic field at which superconductivity can exist in a material is referred to as its critical field, H_c (Figure 3).

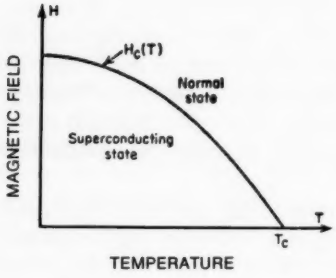

Figure 3 – Critical curve $H_c(T)$ of a metal separating its normal and superconducting states

HISTORY OF ONR'S EARLY ACTIVITIES IN SUPERCONDUCTIVITY*

In the 1940's, the properties of superconductors were widely regarded as interesting but impractical laboratory curiosities. This was the general consensus when during the first year of its existence, ONR sponsored two conferences of its low temperature contractors to review the status of superconductivity and low temperature physics. The first was held in ONR Washington headquarters on June 7, 1946, and the second, at Johns Hopkins University on December 9, 1946. These initial meetings were most successful and by the end of the 1940's, the ONR program became the focus of all the superconducting and low temperature physics effort in the Nation.

The war-born Collins' liquid helium cryostat, developed in 1946 under Army Air Force and OSRD sponsorship, was emerging as a commercially available facility during these years. The way for future technology also was being opened by encouraging theoretical investigations, such as those of Professor F. London at Duke University, which included preparation of a comprehensive two volume treatise on "superfluids." The first volume, which appeared as London's fifth ONR technical report, reviewed the state of the macroscopic theory of superconductivity. The second volume, on superfluid helium, was not to appear until after his death in 1954. Their impact has been profound.

*Much of the material for this section was taken from the article by L. McKenzie, "A View of Science and Technology Sprung from Cryogenics," Naval Research Review, Vol. XIX, No. 1, January 1966, pages 2-13.

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Professors H. Boorse and M. Zemansky constituted another ONR supported team at Columbia that was studying the properties of the superconductors with high transition temperatures—niobium and niobium nitride. The usefulness of superconducting electronic elements in technology was an obvious spur to the backing of their basic research.

The first half of the 20th Century saw Onnes' first liquefaction of helium in 1908 and his discovery of superconductivity in 1911. It concluded with news that an ONR contractor—Professor Giauque had won the 1949 Nobel Prize in Chemistry for his work in approaching the absolute zero of temperature by adiabatic demagnetization of paramagnetic salts. This was the first technique which opened the way to studies of superconductivity below 1°K.

As late as 1952, at an ONR-NSF sponsored low temperature conference the principal speaker stated that low temperature physics represented an ivory tower field of research, a field which would never become commercially practical. The developments which followed in the remainder of that decade and the next, point up the pitfalls of underestimating scientific progress.

RECENT DEVELOPMENTS

One of the first of several major scientific breakthroughs occurred in 1957, when three theoretical physicists, Bardeen, Cooper and Schreiffer developed a theory that explained successfully the microscopic origin of superconductivity in materials. This theory, called briefly the "BCS theory," postulates that in the superconducting state electrons of equal and opposite momenta and spins are weakly bound together. Since electrons have a negative charge and repel each other by coulomb repulsion, any binding or attractive force between them must take place indirectly, such as through the positive ions of the lattice of the material. For materials to be superconducting, this lattice-assisted attractive force must exceed the coulomb repulsive force. In a normal material, there is resistance to the flow of an electric current because the electrons are scattered from the path of the current by vibrating atoms of the material and by impurities and imperfections in its structure. When a material becomes superconducting, the electrical current persits without decay indicating that this supercurrent must somehow be immune to the scattering that affects normal currents.

The involvement of the lattice in the attractive interaction explains the seemingly peculiar fact that superconductivity has never been observed in metals that are usually considered to be the best conductors, such as copper and silver, whereas it is a common phenomenon among the poorer conductors such as lead and tin. The high conductivity of copper and silver is a consequence of the comparatively weak interactions of the electrons with the lattice of these metals. This reduces the

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scattering of single electrons that impairs conductivity in the normal or nonsuperconducting state but it also reduces the attractive interaction of electrons that leads to superconductivity. The attractive force tends to couple together in "bound pairs" those electrons that have equal and opposite momenta and spins. This binding is extremely weak, however, as revealed by the fact that it is disrupted and superconductivity destroyed by thermal vibrations at temperatures just a few degrees above absolute zero. Mechanisms of an attractive force, other than the electron-lattice interaction are under active investigation. Some of these other mechanisms are thought to be promising for higher temperature superconductors. One of the exciting and speculative present-day research areas is directed toward the possible existence of organic superconductors with markedly elevated transition temperatures. Despite the intense efforts of a number of very competent groups, we still do not know what limits the maximum transition temperature to near 20°K, nor do we know if it is possible to develop materials with higher transition temperatures (Figure 4).

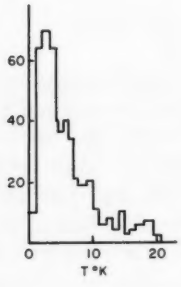

Figure 4 — Number of known superconductors as a function of T_c

By the end of the 1950's, industry was becoming actively interested in superconductivity and began to explore its potential for commercial exploitation. The relatively small sums that ONR and other DOD agencies had been supplying university based research was having both a catalytic and multiplicative effect. Industry was beginning to spend significant amounts of its own funds investigating paths to practical payoffs. A second major breakthrough occurred in 1961 when a group under J. Kunzler at Bell Telephone Laboratories found that a niobium tin compound, Nb_3Sn, remained superconducting in field strengths greater than 90,000 gauss and could also carry high current densities. This discovery of a new class of superconducting materials, called type II superconductors, was of major significance and has formed the basis for the development of compact high field superconducting magnets. They are called type II materials to distinguish them from the earlier known, type I superconductors such as tin, lead and mercury. These

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type I materials lose their superconductivity in magnetic fields below 1 kilogauss. Since superconducting magnets produce no Joule heating, only the energy required to create the magnetic field itself has to be provided. While formerly, large generators were needed for power supplies, the job can now be done with a few car batteries.

Today some 1000 different materials are known to be superconductive. Two alloys—niobium-zirconium (Nb-Zr) and niobium-titanium (Nb-Ti) and the one compound Nb_3Sn—are available commercially. Nb_3Sn has the highest measured critical field (220 kiolgauss) and the second highest critical temperature (18°K) of any superconductive material. A new alloy—a solid solution of niobium, aluminum, and germanium—was discovered about two years ago with a T_c of 20.1°K. At the present time only small quantities of this compound are available and its properties are being actively studied.

Many industrial, university, and government laboratories are continuing to search for new superconducting materials as well as studying the complex electrical and magnetic properties of existing materials. For example, the low temperature research group at the Naval Research Laboratory (NRL) has over the last ten years made a number of major contributions to the field of superconducting materials. Many of the present day materials investigations have as their goal discovering materials having higher critical temperatures, higher critical magnetic fields and greater current-carrying capacity. Of equal importance are those studies aimed at isolating the basic mechanisms that are responsible for superconductivity in compounds, alloys and semiconductors.

The third major property of superconductors are their quantum mechanical behavior. By quantum mechanics, we refer to the wave-like structure of matter that is responsible for discrete orbits of atoms and molecules, rather than continuous orbits as expected from classical mechanics. These discrete orbits arise from constructive and destructive interference of matter waves in precise analog to the constructive and destructive interference that gives rise to diffraction and interference patterns in optics.

There are two major quantum phenomena seen in superconductivity. The first is quantized magnetic flux. This was first suggested by the theoretical physicist Fritz London. It arose from his ideas on the long range order experimentally evident in superconductors. This long range order results from all the superconducting electrons acting like a coherent wave. This discovery of quantized flux was made in 1960 by Deaver and Fairbank in the United States and Doll and Nabauer in Germany. Quantized flux means that in any superconducting ring or hollow cylinder the magnetic flux passing through the cylinder is quantized *i.e.* can have only discrete values which are multiples of the flux quantum. The flux quantum has a value of 2×10 gauss-cm^2, a very small flux indeed.

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In 1962, a young British graduate student of physics, Brian Josephson, was studying the theory of tunneling between two pieces of superconductor separated by a very small non-superconducting normal region with a thickness of order 10^{-7} cm. He was led to predict that the superconducting electron pairs could *tunnel* unhindered from one piece of superconductor through the normal region to the other superconductor. This tunneling observed by Anderson and Rowell within a year, is the second quantum mechanical property of superconductivity. The ability of the superconducting wave to cross small normal regions giving current flow without voltage is called the dc Josephson effect. It corresponds to the superconducting wave penetrating through the thin normal region with no voltage. If the normal region were thick, a current could flow through it only by having a voltage across the region. Such a sandwich type device of two superconductors separated by a thin region of normal material, which may be a metal or an insulator, is called a Josephson junction.

Because the normal region is not a superconductor, a magnetic field can penetrate it. This magnetic field affects the current of the superconducting wave tunneling through the normal region. The detailed functional dependence of the current through the normal region of junction shows properties analogous to optical diffraction as shown in Figure 5. If two junctions are connected in a parallel circuit as shown in Figure 6, the resulting dependence of the current flowing through this circuit on the external magnetic field is analagous to optical two slit interference as shown in Figure 7. Each of the oscillations in the interference pattern correspond to a single flux quantum penetrating into the entire loop circuit. Since the loop circuit can have areas of the order of a square cm, a magnetometer is possible with extraordinary sensitivity. A sensitivity of about 10^{-10} gauss has been observed in the laboratory.

To understand what such sensitivity means in practical terms we can calculate the magnetic fields due to, say, 100 tons of demagnetized steel which has only the magnetization induced by the earth's field of approximately 0.5 gauss (if the steel were not demagnetized the field would be larger). A sensitivity of 10^{-10} gauss corresponds to detecting the magnetic fields of this steel at a distance of more than 10 miles!

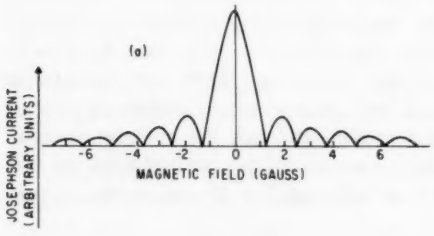

Figure 5 — Dependence of the maximum Josephson current on applied magnetic field for a single junction

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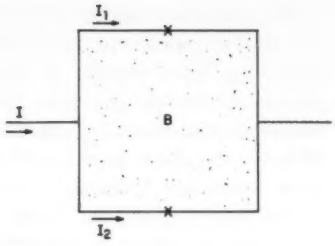

Figure 6 — Two-point contact Josephson junctions in parallel in magnetic field B

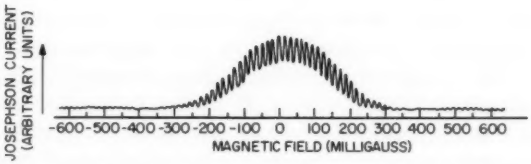

Figure 7 — Dependence on applied magnetic field of the maximum dc current that can be carried by two Josephson junctions in parallel

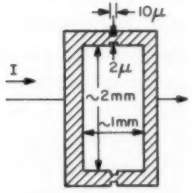

Figure 8 — Two weak link Josephson junctions in parallel

This extraordinary sensitivity is further illustrated by a recent experiment in which the magnetic fields generated by the human heart were easily detected with a superconducting magnetometer outside of the body. These field strengths are about 10^{-7} gauss. (See front cover.)

In addition to the dc Josephson effect there is the ac Josephson effect, in which a voltage is developed across the junction. Consistent with Faraday's Law of electromagnetic induction, this voltage implies a time varying magnetic flux. One can think of the voltage as being due to flux quanta moving through the junction. The voltage produced is directly proportional to the frequency of the motion multiplied by the elementary flux quantum (2×10^{-7} gauss cm^2). This frequency can be thought of in either of three ways: (1) as a frequency of motion of the flux quantum through the junction, or, (2) as a frequency of radiation which is radiated away by the junction if the voltage is supplied to the junction, to provide the energy, or, (3), the frequency of radiation absorbed by the junction which then causes a measureable voltage. The relationship between the voltage V and the frequency ν of the emitted radiation is: $\nu = 2eV/h$, where e is the charge on the electron and h is Plank's constant. Numerically, this gives a value of about 480 megacycles per microvolt. The frequency region in which Josephson junctions show this ac effect can be though of as either very long wave length infrared or millimeter radio waves. The usual region of wave length spans from a few tenths of a millimeter to a few tens of millimeters in wave length.

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The two most widely used types of tunnel junctions are the thin film junction composed of two superconducting films separated by a thin insulating layer, usually a thermally grown oxide. The second type is the point contact junction consisting of a needle of superconducting material on a block of superconductor. In addition to these two types of junctions there are several other types of structures in which superconductors are "weakly" coupled together and exhibit similar effects to the tunnel junctions. Such structures are generally known as "weak links." One variety is the bridge type. It consists of a superconducting film usually about 1,000 A thick with a constriction which is on the order of 2 microns wide and 10 micron long (Figure 8). Such a structure can be fabricated by vacuum evaporation through a mask, by microscribing, or by photoetching a pre-evaporated film. Another variety is fabricated by allowing a molten blob of solder such as the ordinary tin-lead solder to solidify around a superconducting wire with an oxide layer. This variety, called a "Slug," is by far the easiest of any junction to make (Figure 9). The term Josephson junction is commonly used for both the tunnel and weak link junctions.

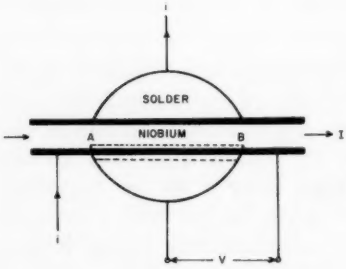

Figure 9 — "SLUG" variety of superconducting junction, made by melting a blob of solder to a superconducting niobium wire with a thin oxide layer

DEVICE APPLICATIONS OF SUPERCONDUCTORS

Magnets

In the last five years a number of spectacular superconducting magnets have been constructed. One of the largest is a magnet at Argonne National Laboratory designed to give a homogeneous magnetic field over its 16 foot (diameter) by 9 foot (height) volume. The field strength can be varied up to 25 kilogauss.

Another large superconducting magnet was designed by AVCO for magnetohydrodynamic power generation. It was a cylindrical bore 6 feet long and 1 foot in diameter and provides a uniform magnetic field of 40,000 gauss transverse to the axis of the magnet. The thermal superinsulations of today are so effective that the hot plasma (at about 3000°C) is maintained with a few inches separation from the superconducting magnet at a temperature close to absolute zero. Magnets

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with fields up to 120 kilogauss and small bores are commercially available from several companies. Today these magnets are routinely used in research laboratories.

Magnets can expect to see applications in a variety of naval and military operations. In mine sweeping the high field strength to weight ratio of superconducting magnets and persistent current operation could permit mine sweeping by helicopter without the need of a power source for the magnet.

Energy storage is another potential application of superconducting magnets. They have an energy density more than one hundred times that of electrical capacitors. At present they are not widely used for this purpose because their switching times are too slow. Large magnets could be also used in extremely low frequency communication as inductors and storage elements.

Manned space flight for long periods requires shielding against radiation. One of the best ways to perform this shielding is to use a large superconducting magnetic to produce a magnetic field that traps incoming charged particles to provide a permanent radiation shield.

Superconducting magnets are also likely to soon be part of our everyday lives. A leading contender for high speed ground transportation is the magnetic levitation of vehicles from the motion of superconducting magnets over conducting tracks. Such a suspension system which can be smooth, and non-contact; is the only one that improves as the velocity is increased. Magnetic levitation may also have application to aircraft carrier takeoff and landing.

Superconducting magnets may have still other naval applications. The zero resistance of superconducting coils, operating in a persistent mode, will not allow the magnetic flux linking the coil to change. Instead, a current flows in the coil to compensate for any external charges of flux. This property could be used for active degaussing in ships by having large superconducting coils that surround most of a ship. The degaussing operation of the coils would be intrinsically automatic in compensating for changes of heading and for changes in the earth's field. This magnetic shielding property has also been used to construct stable zero field test facilities at a number of places.

Motors and Generators

A number of small superconducting, or to be more precise, partially-superconducting motors and generators have been constructed. They all have superconducting stator coils, but the rotor is made of copper and other normal materials to avoid the problems of cryogenic bearings. These superconducting motors exhibit power losses that are less than one-half those of normal motors. The first large superconducting motor,

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built by Britain's IRD corporation, is a 3000 horsepower superconduction homopolar motor, which is now being tested. After testing and operation it may be put aboard a vessel. Because of the high power to weight and cost ratio, superconducting motors and generators may play an important role in our future Navy.

Microwave Cavities and Power Lines

High purity niobium superconducting microwave cavities are being used at Stanford University in the construction of a 500 foot superconducting electron linear accelerator. Another use of niobium, for power transmission lines, is under study. In both cases the power saved by superconductors is more than enough to compensate for the power required in the refrigeration.

These developments in superconducting power transmission lines for urban use, and superconducting microwave cavities for very high power radar for military use appear most promising. For example, a superconducting power line carrying 1700 amperes (685,000 amps/in^2) at 60 hz has electrical losses about 6,000 times less than an equivalent power line of copper at room temperature. Superconducting cavities to be used in linear accelerators at frequencies of about 9 GHz have losses as little as 10^6 times less than copper.

Magnetometers

Ultra sensitive magnetometers using the Josephson effects appear to be of considerable value for submarine detection. By using counterwound sense coils, the superconducting device offers a possibility of an intrinsic magnetic gradiometer which would decrease the earth's background magnetic field noise and extend the useful range for submarine detection. These magnetometer circuits can also be used in a wide variety of other ways such as for position detecting, gravimeters, accelerometers, voltmeters with extraordinary sensitivity of order 10^{-17} volts, seismometers and any other instrument depending on voltage or current measurement.

Infrared Detectors

An additional important use of such Josephson devices is as ultra sensitive detectors of microwave and far-infrared radiation. Used as far-infrared detectors, they have been able to detect 10^{-13} watts in a one-cycle bandwidth. Switching times of the order of 10^{-8} seconds have been demonstrated. The upper frequency limit of operation and their ultimate sensitivity are being actively explored.

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One of the obvious applications of the ac Josephson effect is the generation of coherent radiation in the microwave and submillimeter wave regions. Groups are working on arrays of coupled junctions and tens of milliwatts of useful power output seem feasible.

REFRIGERATION

The cost of refrigeration is an important factor in determining the widespread use of superconducting devices. Figure 10 shows both the capital cost of miniature cryogenic refrigerators and the operating power requirement as a function of the temperature of operation. These curves have a rapid increase in the very low temperature region where superconductivity occurs.

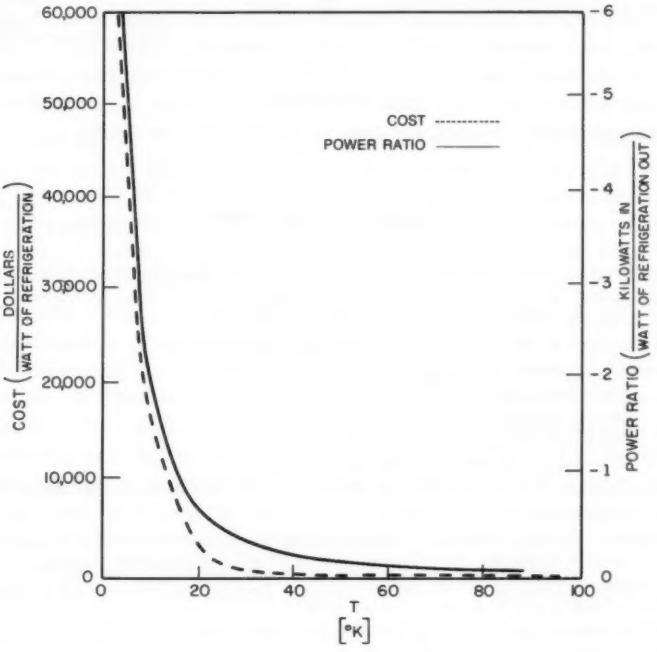

Figure 10 — Cost of refrigeration

Developments taking place now in the field of refrigeration, will dramatically affect the future of superconductivity. Alternatively, system designs that include several superconducting devices operating with one refrigerator will cut the cost of refrigeration per device greatly.

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CONCLUSIONS

The field of superconducting devices is large and growing at an ever increasing rate. In addition to the various devices mentioned, others of promise to DOD are: computer switching elements, delay lines, parametric circuit elements, amplifiers, gyroscopes, direct current transformers, nuclear particle detectors, acoustic detectors—the list is far from exhausted. Superconducting devices during this next decade will offer the Navy important alternatives for existing technologies as well as new possibilities in the field of anti-submarine warfare, shipboard power generation, ship propulsion, magnetic shielding, mine sweeping, mine countermeasures and missile detection and identification. This next decade will see use of many superconducting electronic and electromechanical devices in the fleet. The most exciting possibility is that of superconducting systems for ships and submarines. Some examples are systems with generators, motors, transmission lines, radar, degaussing and mine sweeping coils as well as magnetic and infrared sensors that are all superconducting. These systems could have one refrigerator, and cost substantially less than conventional systems. Superconductivity will indeed provide a cool solution to many Navy problems.

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Flammability and Combustion Research at NRL

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Naval Research Laboratory

Since its early days, the Navy has been vitally concerned with flammability and combustion—in terms of safety, generation of power, comfort, and curiosity. For many years, the Naval Research Laboratory (NRL) has been performing research on various aspects of combustion; four areas of research are presented here which are representative of current scientific interest at the Laboratory. They also illustrate the fact that many facets of study are involved in the broad field of combustion research.

Flammability

The first of these areas of study, which we may call flammability, is sponsored by the Naval Ship Systems Command. The objective of this study is to establish the interrelationships of physico-chemical properties of hydrocarbons with flammability behavior, and to express these in the form of mathematical equations. These relationships have been known in a qualitative sense for many years, but our work is aimed at establishing them in a quantitative way so that numerical predictions may be made.

The relationship of vapor pressure to flammability, particularly as measured by flash points, will be used as an example to illustrate these concepts. Flash point is defined as the lowest temperature at which the vapors over a flammable liquid can be induced to "flash" by an outside source of ignition as the liquid is slowly heated. For example, if a fuel tank is heated slowly, the concentration of fuel vapors in the free space will increase to a point where introduction of an ignition source would cause a flash or flame or even an explosion.

The effect of heating can be expressed also in a quantitative sense as illustrated in Figure 1 which gives a typical vapor pressure curve for a hydrocarbon, showing how vapor pressure or concentration (in a closed system) increases with rising temperature. Figure 1 also shows the two flammability limits for the particular hydrocarbon as a function of temperature in the presence of air. Below the lower flammability limit, the concentration of fuel vapors is "too lean" to burn, and above the upper limit the concentration of vapors is "too rich" to burn.

The intersection (a) of the Lower Flammability Limit curve and the Vapor Pressure curve is the minimum temperature at which the

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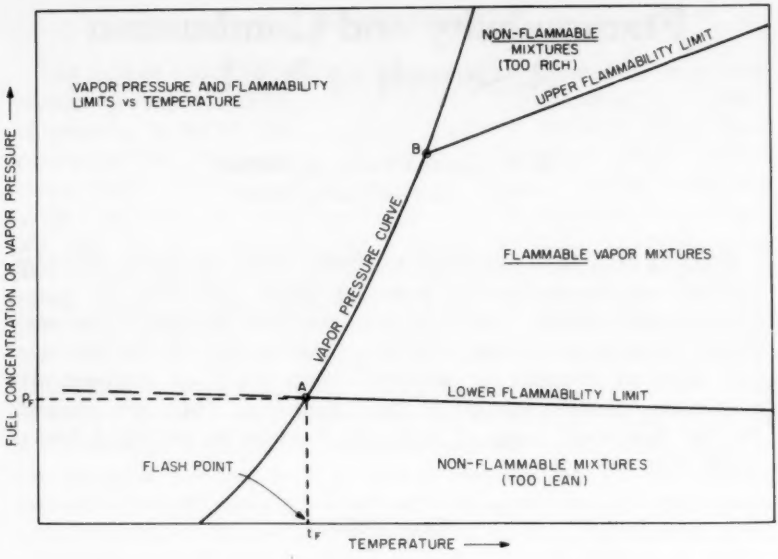

Figure 1

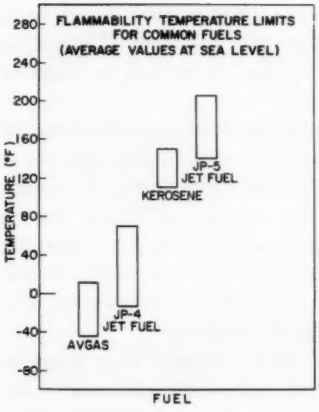

Figure 2

particular liquid would flame (or flash under equilibrium conditions in air. This is the flash point temperature.

The flammability range for a given substance lies between the intersections of the two flammability limit curves and the vapor pressure curve, and can be expressed either by concentration or by temperature.

Flammability ranges for four common aviation fuels are given in Figure 2. All of these fuels are hydrocarbon fuels derived from petroleum. JP-4 and JP-5 are both fuels. JP-4 is a wide-cut gasoline. JP-5 is a high flash point kerosene and is the jet fuel used on aircraft carriers for reasons of safety. At ordinary temperatures, AvGas is too rich to burn, kerosene and JP-5 too lean, but JP-4 is in its flammable range. This is very important from a safety standpoint because a source of ignition in the vapor phase inside a JP-4 tank at ordinary temperatures could cause a fire.

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Flammability of Mixtures

The mathematical equations relating physico-chemical properties to flammability have been extended to mixtures of hydrocarbons. An example of such an equation is shown in Equation 1. Effectively, what this equation states, in a quantitative form for mixtures of hydrocarbons, is that the flash point of a multicomponent hydrocarbon solution is a function of the flash points, concentrations, and vapor pressure-temperature relationships of each component. Figure 3 illustrates one such relationship, showing the effect of composition on the flash point of two different bicomponent mixtures. The curves were calculated before the points were determined experimentally. The coincidence of the data points with the calculations is excellent. Note the very dominant effect

EQUATION FOR CALCULATION OF FLASH POINT OF HYDROCARBON MIXTURES

$$\sum_i \left\{\left[(1642 - T_i')N_i/(1642 - T_M')\right] \times 10^{m_i(T_i' - T_M')/T_i'T_M'}\right\} = 1$$

T_M' = Flash Point of a multi-component liquid hydrocarbon solution

T_i' = Flash Point of component "i"

N_i = Concentration (mole fraction) of component "i"

m_i = Constant (depending on the vapor pressure-temperature relationship for the particular component)

$T' = t\ °C + 230$

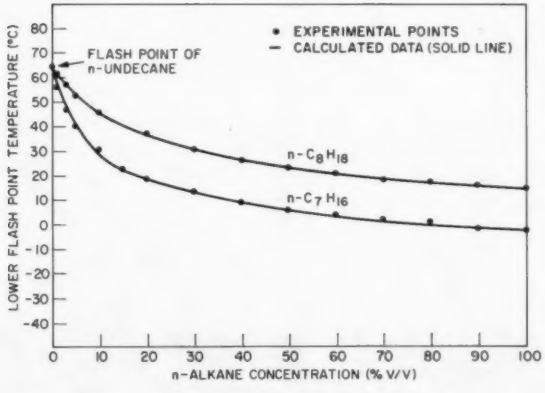

Figure 3

on flammability that the volatile component has, even at low concentrations. This is very important from a safety standpoint, because it shows that the flash point of a given fuel can be lowered dangerously by contamination with a small amount of a more volatile product.

The equations used to calculate flash points of mixtures can be applied to multicomponent systems also. Table 1 shows calculated and experimental values for systems containing up to 6 components, and again the coincidence is excellent.

Table 1
Flash Point Temperatures of Multicomponent n-Alkane Solutions

n-Alkane Concentration (%)						Flash Point (°C)	
Number of C Atoms							
7	8	9	10	11	12	Calculated	Experimental*
50	50	–	–	–	–	5	2
33.3	33.3	–	–	33.3	–	10	10
25	15	–	–	60	–	15	14
20	20	–	–	60	–	17	16
5	5	–	–	90	–	37	37
25	–	25	–	25	25	17	15
20	20	20	–	20	20	16	16
15	15	15	15	25	15	20	20

*Tag-Closed Cup

From a more practical standpoint, Figure 4 shows the flash points for mixtures of JP-4 and JP-5 jet fuels. Here again, note the marked effect of JP-4 on flammability of JP-5 even at low concentrations. This is why aircraft fueled with JP-4 are not allowed to defuel into the aircraft carrier JP-5 tanks. Instead, the JP-4 must be jettisoned.

One important practical result of the present work is that we have recommended strongly that the Navy should hold the flash point of JP-5 fuel at 140°F, even though there has been great pressure to accept a lower flash point temperature. On aircraft carriers JP-5 tankage is close to the skin of the ship, and we have recommended against lowering its flash point by any means (such as by a change of specifications, contamination, or additives) because of potential increased danger to the ship.

Effect of Oxygen Concentration

A second area of combustion research concerns the effect of oxygen (O_2) on ignition and combustion. Man is becoming more and more

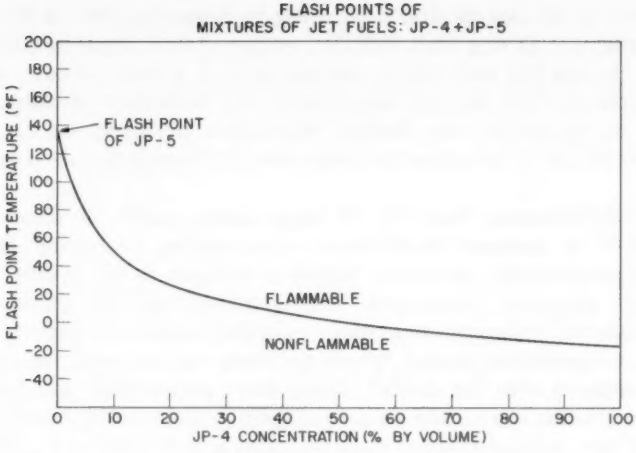

Figure 4

interested in sealing himself in chambers containing unusual atmospheres (Apollo, SEALAB, high pressure O_2 in medicine, *etc.*). One feature of all these is the change in oxygen concentration from normal air.

Two points should be emphasized:

(1) Support of life is dependent primarily on partial pressure of O_2, and

(2) Support of combustion and ease of ignition of materials are dependent primarily on concentration of O_2, not partial pressure.

An example of the need for maintaining similar partial pressures of O_2 in inhabited systems, and how these relate to concentration, is shown in Table 2. Physiologically these chambers are comparable, but they are radically different from a fire hazard standpoint, as we all remember from the Apollo fire in 1967.

Table 2
Oxygen Levels in Various Environments

Environment	Total Pressure (atm)	Concentration of 0_2 (%)	Partial Pressure (atm)
Apollo	**1/3**	**100**	**0.3**
Normal	**1**	**21**	**0.2**
SEALAB II	**7**	**4**	**0.3**

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Prior to the Apollo fire, a fatal fire in February 1965 at the Navy Experimental Diving Unit (NEDU) occurred in a chamber containing 28% O_2 and the rest helium and nitrogen at a total pressure of four atmospheres. This did not sound like a very hazardous situation. However, based on the very limited information available, we calculated that materials in that chamber could burn 10 times as fast as in ordinary air.

Shortly following that fire, we began some studies of several combustibles in unusual atmospheres—atmospheres containing different O_2 concentrations, comparing helium to nitrogen as the diluent, and at various pressures. Essentially, the apparatus used for these studies consisted of a chamber containing a specimen holder (for paper, fabrics, *etc.*) and an ignition source. After a specimen was mounted, the chamber was charged with the desired atmospheric composition and pressure. Measurements were made on ease of ignition and burning rate.

The very marked effect of O_2 concentration on burning rate is shown in Figure 5. We see that doubling O_2 more than doubles the burning rate of paper. Increased pressure also has an effect, but it is smaller. These data show that concentration of O_2 is more important than its partial pressure. Ease of ignition is also highly dependent on O_2 concentration, as illustrated in Figure 6, which shows the limiting conditions for ignition in our apparatus. Here again we see the importance of concentration rather than partial pressure of O_2. Also at given pressures there are lower concentration limits for O_2, just as there are lower flammability limits for fuels. These values vary with the fuel and with the diluent. This kind of information has important implications to control of fires

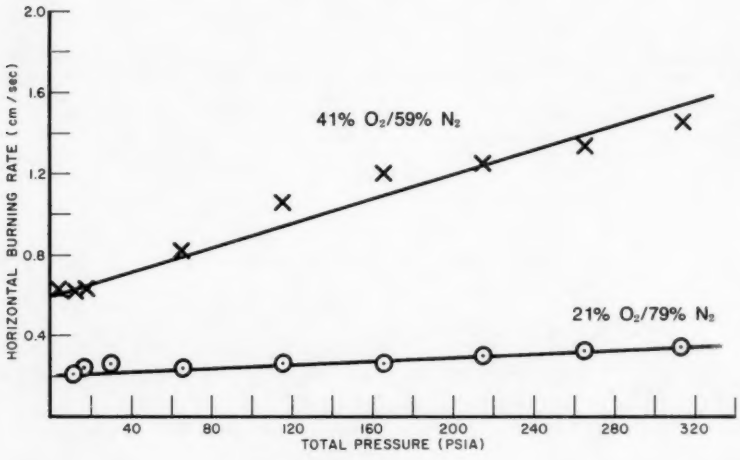

Figure 5

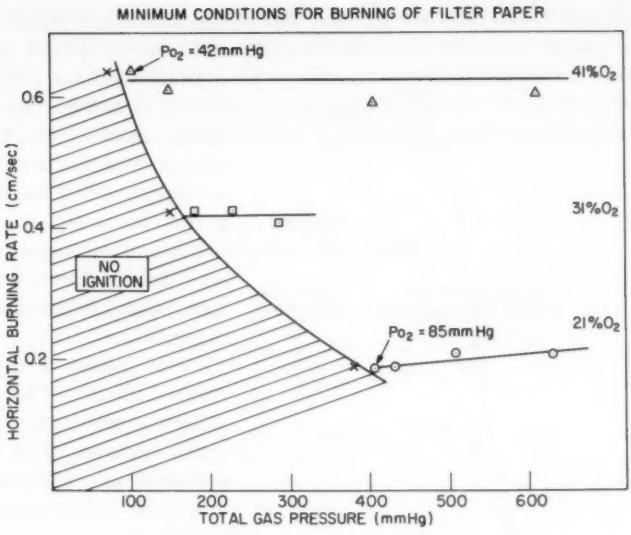

Figure 6

in closed systems. For example, we have recommended maintaining O_2 concentrations in submarines below 21% for reasons of fire safety, rather than controlling it only by means of partial pressure as had been done in the past.

Another important finding was that several common fire-proofing agents which are effective in air did not give protection at O_2 concentrations much above 30%. Here again, recommendations were made to NEDU and others, both in terms of oxygen control and selection of materials which may be used for clothing and furnishings in closed manned chambers.

Chemi-ions

The third area of combustion research concerns the formation of chemi-ions by oxidation of hydrocarbons. This is a relatively new area, and still largely exploratory. Chemi-ions are ions formed as a result of direct chemical reaction such as hydrocarbon flames. They are of interest in connection with developing a better understanding of combustion processes and mechanisms. A few years ago, a small research study on chemi-ions was begun particularly to see if we could produce them at temperatures below flame temperatures, *e.g.*, as induced by surface catalysis.

Experimentally, selected gas mixtures are passed over a heated platinum catalyst in an apparatus containing provisions for measuring

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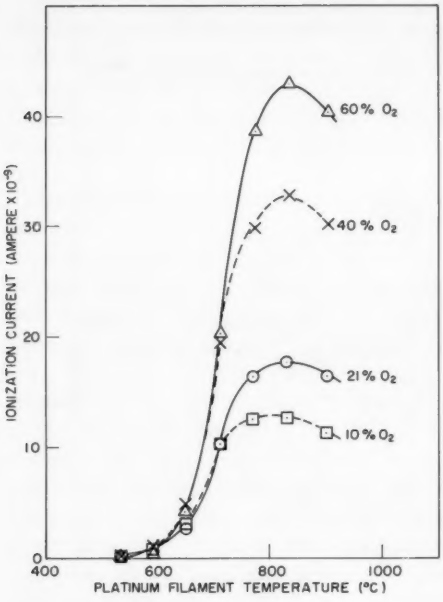


Figure 7

ion currents, to produce data such as in Figure 7. Ions appear at about 500°C, increase in number to a maximum value, and then decrease. A significant point to recognize is that the temperatures involved even for a maximum ion formation, are well below flame temperatures and the generation of thermal ions.

Also shown is the very marked effect of O_2 concentration on generation of ions, again demonstrating its importance in oxidation processes. Such behavior seems logical enough until we examine Figure 8, which shows that the extent of oxidation actually decreases with increasing O_2 concentration. The effect of O_2 concentration on ion formation is obviously then not related to extent of reaction. Instead, we postulate that the degree of ionization is related more to selective adsorption and activation of reactants on the catalyst surface.

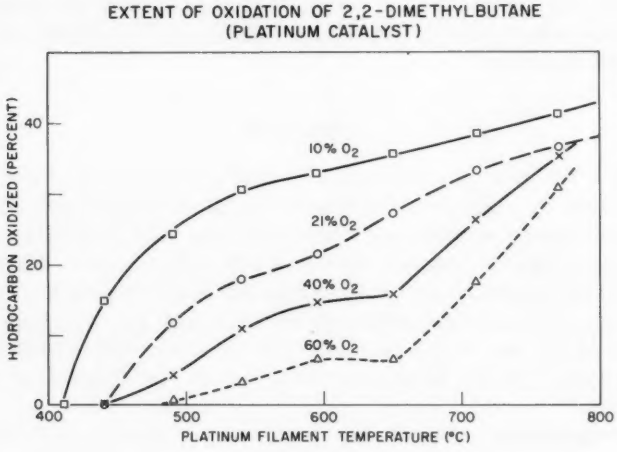
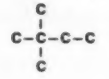
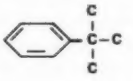
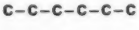


Figure 8

One of the reasons we feel this way is that the effect of chemical structure of the hydrocarbon being catalytically oxidized on ion formation is very marked. Table 3 shows that ion yields on catalytic oxidation can vary by a factor of 1,000 as a result of differences in structure. It also appears that branching of the hydrocarbon skeleton enhances ion formation.

Table 3
Maximum Ion Yield

HYDROCARBON	SKELETAL STRUCTURE	COULOMBS/MOLE HYDROCARBON BURNED
2,2-Dimethylpropane		2.28
2,2-Dimethylbutane		1.26
tert-Butylbenzene		0.13
n-Hexane		0.03
Benzene		0.002

So far there is much that we do not understand about the generation of chemi-ions and the roles they play in the combustion process, but this makes them all the more exciting from a research standpoint.

"Cool Flames"

We would like to mention briefly one additional area of research that has been reactivated recently. This is the study of "cool flames" and related phenomena. Some years ago, during studies on spontaneous ignition, we developed a device called the Vertical Tube Reactor for the study of "cool flames" and other flame processes. As is illustrated in Figure 9, we found that on passage of "fuel rich" vapors through a hot tube, at a given O_2 concentration, a "cool flame" appears. "Cool flames" are ghostly flames which emit a bluish light and

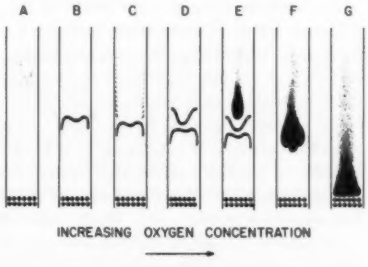


Figure 9

do not get hotter than about 450°C. As the O_2 is increased, other succeeding flame stages appear. Effectively what we can do is to pull a flame apart in both space and time into its various stages. The positions of these stages are highly dependent on the chemical structure of the hydrocarbon being burned. Since highly active species exist in these stages as evidenced by light emission at low temperatures, it is conceivable that a population inversion might exist in some of these energized species. If so, then these might be induced to lase, in which case we would have a new kind of chemical laser. It's a very exciting prospect, because in addition to our search for a possible laser, it is bound to increase our knowledge of that very important subject—the combustion process.

CAPT Holmquist Receives Award

CAPT Carl Holmquist, Deputy Chief of Naval Research, has been presented with the annual Award of Merit by the United States Naval Institute. The award is for his outstanding service to the Institute for his essays in the annual *Naval Review* and his articles in the *Naval Institute Proceedings*. Another article by CAPT Holmquist, "Developments and Problems in Carrier-Based Fighter Aircraft" is in the May issue of the *Naval Institute Proceedings*.

Research on Underwater Speech and Hearing Problems

The Communication Sciences Laboratory (CSL) is presently conducting an extensive program of research on underwater speech communication supported by the Physiological Psychology Branch of the Office of Naval Research and by the Navy's Deep Submergence System's Program. Included in the total program are investigations of underwater speech production, underwater speech reception, underwater sound localization, various underwater communication aids, phonation and sound localization in dolphins, and so on. Although precise methodologies have been available for such research in air, comparable methodology for underwater communication had to be developed—a need that was met by a Diver Communication Research System. The system provides for experimental control of diver positioning, stimulus presentation and subject response. DICORS was the basis of two scientific exhibits during 1967 and one in 1968.

At the 45th Annual Convention of the American Speech and Hearing Association at Chicago, the Communication Sciences Laboratory presented an exhibit that was broader in scope than those of previous years. Specifically this exhibit provided coordinated information of the experimental results of three related research programs focusing on diver communication problems. The three programs include investigations of: (1) intelligibility distortion created by speaking in exotic gas mixtures, principally HeO_2, (2) speech distortion created by speaking in a fluid environment, and (3) the unexpected ability by humans to localize sounds underwater. Also included in the exhibit were basic diving and research gear—but the stress was on inderwater communication systems (communicators, helmets, face masks, *etc.*), HeO_2 unscramblers, and other relevant research equipment.

As part of this effort, ASHA awards two sets of prizes to scientific exhibits; the awards are for Scientific Merit and Excellence of Presentation. Our exhibit won the First Award for Scientific Merit and the Second Award for Excellence of Presentation.

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Ocean Engineering Technology at the Marine Physical Laboratory

Oceanographic research requires special and sometimes unique tools and equipment. These are especially needed to explore and study the ocean environment by remote means. Recently developed by the Marine Physical Laboratory under sponsorship of the Office of Naval Research are the Ocean Research Buoy (ORB) and Remote Underwater Manipulator (RUM) which will contribute toward such Navy-oriented efforts as ASW, Man-in-the-sea programs, deep ocean search and rescue capabilities and long range surveillance.

ORB (Oceanographic Research Buoy)

The MPL has recently been conducting a program to demonstrate the capability of RUM. Thus far the vehicle has been operating from ORB at depths to 1200 feet in a series of continuing sea tests on the sea floor off San Diego.

ORB, a 45-foot square vessel displacing approximately 180 tons, was developed by the Marine Physical Laboratory to serve projects at the laboratory which require the launch, retrieval, implantation or handling of large eqiupments or systems in the open ocean. Among these are:

1. "RUM" (remote underwater manipulator); remotely controlled, bottom crawling vehicle.

2. "Benthic Laboratory," an electronic control and data transmission center, remotely operated and maintained on the sea floor.
3. Acoustic transducers and hydrophone arrays.

ORB is designed to follow the motion of the sea surface as closely as possible, in order to simplify the task of placing and retrieving large objects in the ocean. The vessel has a center well of 15- by 20-foot area which can be opened to permit equipment to be lowered through it. Loads up to 12 tons are safely handled with a system that includes a number of automatic control features, and can be lowered to a maximum depth of 10,000 feet. The supporting cable also serves simultaneously to transmit as much as 30 kilowatts of power to the remote equipment, and to return from it a variety of data, including television video signals.

ORB is 24 feet high from keel to helicopter deck. It has no means of self-propulsion and must be towed to and from operating areas. The vessel is equipped with diesel generating sets to provide 90 kilowatts of electrical power. ORB's equipment also includes a normal amount of navigation aids, communication and safety equipment. It carries fuel and water for a stay of up to 45 days while moored on station. Personnel rotation at sea where necessary may be accomplished by either small boat or helicopter.

In addition to laboratory work spaces and machinery space, ORB is equipped with complete living facilities for 12 people including 4 crew members.

The "ORB" concept originated with Dr. Victor C. Anderson, Associate Director of the Marine Physical Laboratory. Preliminary design was carried out by Dr. Anderson, Associate Engineer F. N. Biewer and Marine Coordinator E. D. Bronson. The firm of L. R. Glosten and Associates of Seattle provided the Naval Architect services for final design. Construction was accomplished by California Steel Fabricating and Welding Engineering Corporation of San Diego under the sponsorship of the Office of Naval Research. The design of the buoy ORB emphasized simplicity and economy of construction and operation, functional utility, and minimum maintenance.

RUM is a remotely controlled, tracked sea floor work vehicle which has been developed under the sponsorship of the Office of Naval Research at the Marine Physical Laboratory for use as a research tool in sea floor technology experiments.

The hull, tracks, and suspension system of the RUM vehicle are those of an "ONTOS," a surplus Marine Corps tracked rifle.

All power, telemetry for control and instrumentation, sonar, navigation aids, and television are transmitted over the single coaxial umbilical cable connecting the RUM to ORB.

The vehicle is propelled by two independently controlled reversible 7-1/2 horsepack direct current motors, one driving each track. Other equipment includes two television cameras, eight 500 watt lights, a scanning sonar, depth sounder, magnetic compass, an acoustic transponder navigation system and numerous other kinds of instrumentation to monitor operational conditions.

All of the electrical and electronic components with the exception of the TV cameras and lights are immersed in oil and operate at ambient pressures of up to 5000 psi.

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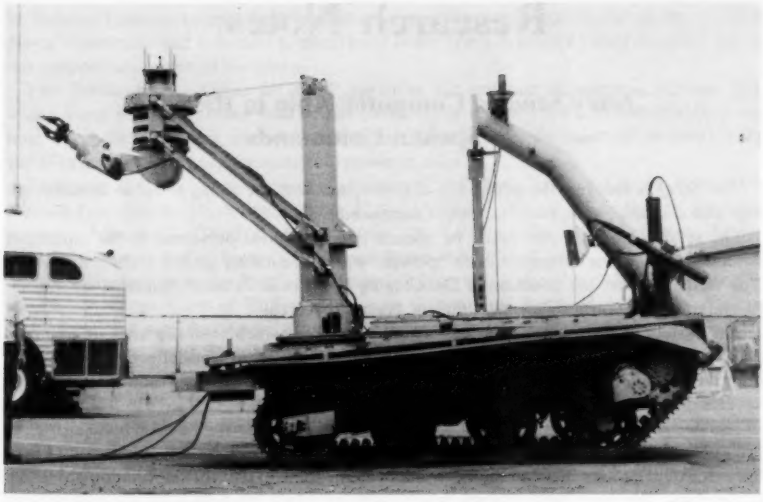

RUM (Remote Underwater Manipulator)

The manipulator is capable of working off either side or to the rear of the vehicle and is capable of exerting 50 pounds of force in any direction at full arms length. In addition the manipulator boom is equipped with a hook capable of lifting loads of up to 1000 pounds and moving them about on the ocean floor. The manipulator boom swings in an arc of about 300° around a king post located at the rear center of the vehicle. The boom is raised and lowered by a motor-driven wire rope topping lift.

The portside TV camera is boom-mounted with the pivot point near midway on the port side. The camera stows forward for driving but may be swung in a wide arc away from the side of the vehicle and around to the rear for close-in viewing of the manipulation areas. The starboard camera is mounted on a dolly which may be positioned anywhere from forward for driving to the rear for manipulation viewing.

Two telemetry systems are used for control and instrumentation, one, a time multiplex system providing 64 channels each way, up and down the cable, the other an amplitude modulated carrier system with four carriers transmitted down the cable and eight carriers returned.

During operations the vehicle is launched through the well on ORB, lowered to the sea floor and the cable tensioning system set for a reasonable tension from 5000 to 10,000 pounds depending on bottom conditions and depth of water. Once RUM is on the bottom it serves as a more than adequate anchor for ORB. As RUM drives across the sea floor it tows ORB across the surface above it at speeds up to one knot. The cable constant tensioning system on ORB automatically pays in or pays out cable as needed.

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Research Notes

Navy Studies Computer Able to Respond to Spoken Commands

The Navy is studying the possibility of a computer with the ability to sense its surroundings and respond intelligently to spoken commands.

The robot type computer could be trained to assist naval personnel in the control of complex engineering systems and be operated without requiring special technical training. The study is under the direction of Dr. Charles Hendrix at Telluron, Santa Monica, California, under a contract with the Office of Naval Research.

The system is not the conventional digital computer, which basically adds up numbers at great speeds in a sequential process, but rather utilizes a parallel process patterned after the brain. This means that, just like the human brain, this type of machine can perform several different procedures simultaneously.

The design of the computer is based on the living nervous system whose building blocks are neurons or nerve cells. The machine uses artificial neurons or "neuromimes." These are electronic circuits that can mimic or duplicate to some extent the information processes of neurons. The neuromimes when interconnected into a network form the rudimentary brain of a computer, which is also called an "operant-conditionable" machine. The term refers to the fact that the machine can be trained by modifying its responses through "punishment" or "reward" signals.

When a message is given to the network, some of the neuromimes fire in response to the message. If the response is incorrect or one not desired by the trainer, he can "punish" the neuromimes that send the unwanted responses by suppressing or preventing them from firing. This "punishment" has the effect of inducing the network to try a new way to solve the problem. At the same time, the group of neuromimes which respond favorably are encouraged or "rewarded" by the trainer strengthening their signals. This process is repeated until the desired answer or response is obtained.

Once trained to perform various tasks, the machine would execute them faithfully when given the appropriate command. Aboard ship it could be used to help in a variety of tasks from navigating the ship to preparing the meals. It could assist a pilot in the operation of his aircraft by handling complicated procedures as he directs. The computer could not only perform in response to vocal commands and instructions as well as other types of inputs but could also answer the operator by voice.

Preliminary tests with a network of only 16 neuromimes have given encouraging results. The present effort is aimed at finding ways to produce a great number of artificial neurons and to devise schemes to connect them into a simple computer "brain." The current study is intended to produce a design of a complete prototype system consisting of 3000 neuromimes that will be both workable and economical to manufacture.

Navy Science Cruiser Program

The Navy Science Cruiser Program was established by the Chief of Naval Operations in 1958 to encourage the nation's youth to develop an active interest in science. Specifically, it is aimed at encouraging outstanding high school students whose scientific projects and talents are of potential interest to the Navy.

Each year Science Service Inc. sponsors fairs for high school students throughout the country. At 225 regional, state, and district science fairs, the Navy selects winners for

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its Science Cruiser Award. Each winner is presented a certificate signed by the Chief of Naval Operations and is invited to participate in the Navy Science Cruiser Program during the summer as a guest of the Navy.

The Public Affairs Office for ONR monitors the program in selecting Science Fair winners and furnishing them with details on the Cruise. The Public Affairs Offices at the host Navy facilities plan the programs, which include visits to points of interest at the naval bases as well as nearby industrial research sites.

This year the U.S. Navy awarded certificates and Navy Science Cruiser Awards to Ronald Lee Amey, 17, William Allen H.S., Allentown, Pa., for "Analytical Study of Balanus Adhesive"; David Andy Benjamin, 18, Lewiston Sr. H.S., Lewiston, Idaho, for "Polywater"; Randy Brown, 16, Grand Blanc H.S., Grand Blanc, Mich., for "Effects of Methylcholanthrene on Rats"; D. Liane Cochran, 17, Lake View H.S., Chicago, Ill., for "Biochemical Study of Chlorellin, A New Antibiotic"; Larry Hayward, 16, Eureka H.S., Eureka, Kans., for "Space Ferry: Development of a Variable Winged Lifting-Body." David Kuykendall, 17, Pisgah Sr. H.S., Canton, N.C., for "Effect of a Rhizobiophage on the Nodulation of *Glycine max*"; James D. G. Lindsay, Jr., 17, Los Alamos H.S., Los Alamos, N. Mex., for "Superconductivity in Niobium-Titanium-Vanadium Alloys"; Bruce Clyde Marusich, 18, Surrattsville Sr. H.S., Clinton, Md., for "*Staphylococcus aureus* Challenge and Hypobolic Pressure"; Debbie Anne Meloy, 17, W. T. Woodson H.S., Fairfax, Va., for "Visual and Radio Investigation on the Nature of Jovian Decametric Emissions"; Steven Shore, 16, Martin Van Buren H.S., Queens Village, N.Y., for "Theoretical Study of the Ejected Nova Atmosphere." Certificates were awarded to the following alternates: Robert J. Herko, 15, Piscataway H.S., Piscataway, N.J., for "Refinement of the Gas Chromatography Detection System"; Edward R. Abramczyk, 15, Rome Catholic H.S., Rome, N.Y., for "Magnetic Effect on a Transistor"; Jo Ann Freedlander, 16, Miami Killian Sr. H.S., Miami, Fla., for "Tolerance System of the Avian Embryo Induced with Bovine Gamma Globulin"; Rodney Harell Trotter, 16, Coronado H.S., Lubbock, Texas, for "The CO_2 Laser"; Lee Robbins, 17, Martin Van Buren H.S., Queens Village, N.Y., for "Search for a Preventive for Tobacco Mosaic Virus"; Paul T. Kolen, 18, Grand Rapids Union H.S., Grand Rapids, Mich., for "Sectional Magnetic Focusing in a Six-Inch Cyclotron"; Stephen Charles Durst, 17, Anoka Sr. H.S., Anoka, Minn., for "Development of Cardiac Replacement and Assist Device"; Elaine Kmiec, 17, Sam Houston Sr. H.S., Houston, Texas, for "Emergence of the Chameleon Chemical"; Marilyn Hudak, 16, St. Dominic Academy, Jersey City, N.J., for "Comparative Experimentation Involving Symbionts, Photoperiods, and Grafting in Hydra"; Gary Allan Uhazie, 17, Warren H.S., Warren, Mich., for "Measurement of Microwave Field Patterns With Photosensitive Probes."

Operation Cherry Blossom

Three teen-aged finalists at the 21st International Science Fair have been selected to go to Japan in January to exhibit their winning projects as representatives of the United States Armed Forces.

Debbie Anne Meloy, 17, W. T. Woodson H.S., Fairfax, Va., for "Visual and Radio Investigation on the Nature of Jovian Decametric Emissions," selected by the U.S. Army; James D. G. Lindsay, Jr., 17, Los Alamos H.S., Los Alamos, N.M., for "Superconductivity in Niobium-Titanium-Vanadium Alloys," selected by the U.S. Air Force; Ronald Lee Amey, 17, William Allen H.S., Allentown, Pa., for "Analytical Study of Balanus Adhesive," selected by the U.S. Navy will be flown to Japan to exhibit at the 14th Annual Japan Student Science Awards' Science Fair in Tokyo in January 1971.

(Continued on Inside Back Cover)

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On the Naval Research Reserve

New Special Assistant for Research Reserve

CAPT Ross A. Hill, USNR, reported aboard on 18 May 1970 as Special Assistant to the Chief of Naval Research (Research Reserve). His predecessor, CDR Henry E. Bates, USNR retired on 1 May 1970. He plans to make his home in California.

Prior to reporting to ONR, CAPT Hill was a Program Coordinator in the Aviation Plans and Requirements Division of the Deputy Chief of Naval Operations (AIR) in the Office of the Chief of Naval Operations. He has been a TAR officer since 1953 with duty assignments as NAS, St. Louis, Missouri; NAS, Willow Grove, Pennsylvania; NARTU, NAS, Norfolk, Virginia, as well as with fleet aviation squadrons.

CAPT Hill received his commission as Ensign and his Naval Aviator designation in 1944. He is a native of Michigan and resides with his family in Alexandria, Virginia.

Promotion Selections

There were 5,065 Naval Reserve line officers selected for promotion to Lieutenant by the Fiscal Year 1970 Reserve Selection Board. Fourteen were members of the Research Reserve Program.

	NRRC		*NRRC*
Anderson, David J.	13-4	Marshall, Eric M.	4-4
Chickering, Howard A.	12-3	Masters, John H.	5-4
Gilligan, Thomas J., Jr.	3-1	Sanders, Robert C.	1-1
Herbert, Algird T., Jr.	4-13	Schneider, Wayne G.	9-1
Kahler, Bruch E.	3-1	Simpson, Paul D.	1-7
Kidder, Paul R.	4-4	Wittreich, George N.	1-7
Lathrop, Granger P.	12-3	Yeamans, Joseph W.	3-2

Thirteen of the officers selected were from the new field and one from the old. Other statistics based on the records of the Research Reservists selected for promotion are:

Year of Birth		*Date of Rank*		*Designator*
Earliest	1942	Earliest	12-3-65	1105:13
Latest	1944	Latest	2-2-67	1405:1

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Research Reservists Served as Judges at Science Fairs

Many Research Reservists throughout the United States served as judges at the 225 regional and state science fairs in connection with the Navy Science Cruiser Program. This Program is designed to encourge the nation's youth to develop an active interest in science.

Additionally, 15 Research Reserve officers served as judges at the International Science Fair held 10-15 May in Baltimore, Maryland. Six of these judges were from the local company—NRRC 5-4, Baltimore, Maryland.

Field Trip of NRRC 3-4

Sixteen members of Naval Reserve Research Company 3-4 Rochester, New York and nine other officers from the Rochester area performed weekend active duty for training (17-19 April) at the major NASA launch center for manned and unmanned space missions. The men toured the John F. Kennedy Space Center, facilities of the U.S. Air Force Eastern Test Range and U.S. Navy nuclear powered submarine USS Pargo (SSN-650). Numerous special laboratories and spaceport testing facilities were also visited during the three-day training period. Launch complex 39, an immense facility designed and developed to accommodate the massive Apollo/Saturn V space vehicles.

NRRC 8-7 Sponsors Fifth Research Reserve Seminar

Seventy Reserve Officers from all sections of the United States attended the Fifth Research Reserve Seminar in Applied Research recently held at Sandia Base, Albuquerque, New Mexico. The focus of the seminar was on the Special Weapons Program and other research in the Southwest, the site of many special weapons and nuclear research facilities.

Naval Research Reserve Company 8-7 of Albuquerque hosted the seminar which included trips to the Los Alamos Scientific Laboratory, New Mexico Institute of Mining and Technology in Socorro, University of New Mexico in Albuquerque, and the Lovelace Foundation in Albuguerque. Dr. Herbert H. Hughes of NRRC 8-7 served as seminar chairman.

The seminar was opened with a welcoming address by CAPT Carl O. Holmquist, USN, Deputy and Assistant Chief of Naval Research, Office of Naval Research, Washington, D.C. VADM Lloyd M. Mustin, USN Director, Defense Atomic Support Agency addressed the seminar in the second week as did LTGEN H. C. Donnely USAF (RET.), manager, AEC, Albuquerque Operations Office. CDR H. E. Bates, USNR Special Assistant to the Chief of Naval Research (Research

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Reserve) was on board during the second week to address the seminar and answer questions about the research reserve program.

Weekend Program for 12-3

This year NRRC 12-3 Stanford, California, has scheduled several Saturday field trips to explore areas of technical interest more deeply than is possible during regular drill periods.

The field trips are all day sessions. Programs undertaken during the current fiscal year include:

- A briefing by the Oceanography Department of the U.S. Naval Postgraduate School, Monterey.
- A briefing and tour of the San Francisco Bay Area Rapid Transit System.
- A briefing and tour of the 12th Coast Guard District search and rescue operations at Alameda, Treasure Island, San Francisco, and San Francisco International Airport plus a tour of the new CG Cutter RUSH.
- A symposium by the Electrical Engineering Department of the U.S. Naval Postgraduate School entitled Applications of Electromagnetic Sensing in the Navy, cosponsored by NRRC 12-8.
- A tour of the recently refurbished attack carrier Midway (CVA-41) plus a tour of the 1100 ft drydock and specialized shops at the San Francisco Bay Naval Shipyard, Hunters Point.

The success of these programs has been enhanced by the large turnout from 12-3, one of the larger Research Reserve companies.

Dr. Shapiro Elected to Post on American Physical Society

Dr. Maurice M. Shapiro, Chief Scientist of NRL's Laboratory for Cosmic Ray Physics, has been elected Vice-Chairman of the new Division of Cosmic Physics in the American Physical Society. Under the bylaws of the Division, Shapiro is also Chairman-elect for 1971.

The impetus to set up the Division of Cosmic Physics, was provided by a petition by some 200 members of the Physical Society. Formation of the Division was authorized by the Council of the Society, and President Luis Alvarez last year appointed an Organizing Committee, headed by Dr. Shapiro.

Already the Division of Cosmic Physics has sponsored a series of stimulating symposia on high-energy astrophysics and cosmic rays, including sessions on neutron stars and pulsars, cosmic X-rays and gamma-rays, gravity waves and relativity.

Members of the American Physical Society who wish to enroll in this Division may apply directly to the APS office in New York, or may telephone NRL extension 2642 for information.

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Alternates for "Operation Cherry Blossom" are: Lance S. Smith, 18, Billerica Mem. H.S., Billerica, Mass. (U.S. Army); Virginia A. Mann, 16, Terry Parker Sr. H.S., Jacksonville, Fla. (U.S. Air Force); and Bruce Clyde Marusich, 18, Surrattsville Sr. H.S., Clinton, Md. (U.S. Navy).

This special award was sponsored jointly by the three services and was announced here today at an awards convocation. ONR will provide the escort officer.

NRL Improves Air Purification Methods

Naval Research Laboratory scientists in the Chemistry Division have developed a new sampling and analysis method that improves the selection of substances used for the oxidation of hydrocarbons in closed atmospheres.

The development by Dr. J. Enoch Johnson and associates at the Laboratory is important as a method to purify atmospheres in submarines, hyberbaric chambers, buildings, air terminals and other closed areas.

The method involves use of a novel multi-port, axial sampling technique which can handle multiple contaminants that vary in the ease of oxidation.

The substances or catalyst selection for this use is critical because the impurities are present in low concentrations in closed areas and may be several different compounds.

Dr. Johnson and his co-workers, Dr. F. S. Thomas and Mr. J. K. Musick report that the new method speeds the testing of catalysts by development of new ways to measure the efficiency of the many chemical combinations that might be used in air purification. The scientists have derived new mathematical formulas for use in the catalyst comparisons.

Dr. Johnson said that most contaminants in submarines and other closed atmospheres are hydrocarbons which are normally removed or reduced by oxidation. However, in a typical air purification situation, there will be a number of different contaminants which may vary considerably in their concentration and their rate of oxidation.

The new systems by Dr. Johnson and his associates enable them to test many catalysts in a minimum time and develop the most efficient materials and procedures for air purification in closed areas.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Washington, D.C., 20360. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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Shown is a chamber designed and built by Dr. David Cohen of MIT Francis Bitter National Magnet Laboratory which virtually screens out all extraneous magnetic field, including the earth's own magnetic field. The weak magnetic fields produced by the electrical activity of the human heart can be sensed by use of an ultra-sensitive superconducting magnetometer, located inside the magnetic field-free chamber. This magnetic sensor, called a "SQUID" (for Superconducting Quantum Interference Device) was developed by Dr. James Zimmerman of the National Bureau of Standards Research Laboratory at Boulder, Colorado. It is housed in a liquid helium dewar located near the subject's chest. A recording of the magnetic field data from the heart (magnetocardiogram) is shown in the upper trace; on the lower trace is an electrocardiogram taken the next day of the same subject. *See page 9.*

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